

**AUTOMATIC MODULATION AND RF CARRIER LEVEL  
CONTROL OF SYNC SUPPRESSED TELEVISION SIGNALS**

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1997..

**BACKGROUND OF THE INVENTION**

The present invention relates to methods for  
automatically controlling the amplitude modulation  
of video signals. Both the absolute carrier level  
and the depth of modulation are controlled. The  
invention is suitable for use with unscrambled  
television signals as well as television signals  
that have the horizontal synchronization pulse  
suppressed to prevent detection of the signals by  
unauthorized persons, e.g., pirates.

A composite video signal such as one which  
conforms to the NTSC standard includes picture  
luminance and chrominance information as well as  
timing information for the synchronization of  
scanning and color processing circuits at a  
receiver. At the end of each line scan at the  
receiver, a horizontal synchronizing pulse (HSYNC)  
commands the scanning circuit to return the scanning  
beam to the left of the screen to begin scanning a  
new line. Similarly, at the completion of each  
field or frame, a vertical synchronizing pulse  
(VSYNC) commands the scanning circuit to return to  
the top of the screen to begin scanning the next  
field or frame. The return period is known as the  
vertical blanking interval.

Accordingly, the television signal may be scrambled by altering the normal position and/or amplitude of the synchronization pulses. Such techniques for scrambling the video portions of television signals are well known. For example, U.S. Patent 3,813,482 to Blonder discloses a system for transmitting television signals where the video is scrambled by suppressing the vertical or horizontal synchronization pulses to produce a shifting or rolling scrambled picture. U.S. Patent 4,542,407 to Cooper et al. discloses an apparatus for scrambling and descrambling television programs in which the horizontal synchronization information is suppressed at a cable television (CATV) headend, and then regenerated by a subscriber's cable television converter. U.S. Patent Numbers 4,095,258 to Sperber, 4,163,252 to Mistry et al., and 4,571,615 to Robbins et al. describe schemes for decoding scrambled television signals.

In particular, by suppressing the horizontal synchronization pulses below the average value of the active video, a television receiver attempts unsuccessfully to lock horizontally on to random peaks of the active video rather than the HSYNC pulses. Additionally, the loss of effective horizontal synchronization prevents the receiver from properly utilizing the color burst signal which is associated with the HSYNC pulse, so that color reproduction is also faulty.

In order for a receiver to restore (i.e., descramble) the scrambled video signal, the

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stable amplitude modulator is used with automatic gain control of the video signal.

However, suppression and subsequent restoration of synchronization pulses is hampered by variations in amplitude modulation equipment, which may be at a CATV headend or a remote location, for example. Conventional RF carrier circuitry is subject to drift and other inaccuracies due to humidity and temperature variations, as well as changes due to degradation over the lifetime of the equipment, for example. Modulation level discrepancies can cause flickering or other undesirable brightness changes in the recovered video image.

Thus, such modulating circuitry must be periodically adjusted by a technician using metering equipment to ensure accuracy. This solution is inefficient, in particular, when the modulation circuitry is remotely located. Additionally, the problem of drift in the modulation accuracy is not solved.

Accordingly, it would be desirable to have a system for automatically controlling the amplitude modulation level and depth of modulation of a television signal. The system should be suitable for use with sync suppressed signals, including signals with VSYNC and/or HSYNC suppression, as well as non-suppressed signals. The system should be suitable for use with multiple levels of sync suppression. The system should also be suitable for use with signals with normal (e.g., non-inverted) as well as inverted active video portions.

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The present invention provides a system having the above and other advantages.

### SUMMARY OF THE INVENTION

In accordance with the present invention, methods are presented for automatically controlling the amplitude modulation of a video signal.

5 In one embodiment, an automated modulation circuit for processing a video signal comprises means for detecting a comparison portion in the video signal having an associated amplitude. The comparison portion may be a horizontal or vertical  
10 synchronization pulse. For example, a horizontal sync pulse may have a sync pulse tip at -40 IRE (at baseband) for a non-scrambled video signal. Means are provided for normalizing the comparison portion amplitude according to a reference level. The  
15 reference level may correspond to a video level, e.g., 50 IRE, about which inversion of the active video occurs. However, inversion is not required. Normalization involves scaling the comparison portion to the reference level using a multiplier.

20 Means are provided for detecting a reference pulse having a reference pulse amplitude at the reference level in the video signal. For example, a reference pulse may be provided in a horizontal or vertical sync pulse, or in a vertical blanking  
25 interval. The reference pulse may serve as an inversion level pulse when inversion occurs.

Means are provided for generating a first error signal corresponding to a difference between the normalized sync pulse tip amplitude and the reference

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pulse amplitude. For example, sample and hold circuits may obtain samples of the sync pulse tip and the reference pulse. An A/D converter converts the samples to digital form for processing by a  
5 microprocessor controller, which then determines an appropriate error signal based on the relative magnitudes of the two samples.

Means responsive to the first error signal adjusts a depth of modulation of the video signal.  
10 The first error signal can bias the video signal prior to modulation by an RF carrier.

When the sync pulse tip is attenuated, e.g., in a scrambled signal, means are provided for correcting the comparison portion amplitude to remove the  
15 attenuation. For example, a comparison portion which is a sync pulse tip may be attenuated by 6 dB or 10 dB, in which case appropriate multipliers are used to restore the sync pulse tip to the -40 IRE level, or to another non-attenuated level depending on the  
20 video standard in effect.

The means for generating a first error signal generates an error signal corresponding to a difference between the normalized and corrected comparison portion amplitude and the reference pulse  
25 amplitude.

The means responsive to the first error signal for adjusting a depth of modulation of the video signal comprises a microprocessor controller for converting the first error signal to a first  
30 adjustment signal. This may be achieved, for example, using a memory which stores a look up table

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for converting the error signal to an adjustment signal. Threshold ranges may be used to provide a range where a zero or near zero error signal results in a zero adjustment signal. The adjustment signal  
5 may further be a function of a bit error of the error signal. A first charge pump receives the adjustment signal and provides a corresponding modulation depth control signal, which is coupled to bias the video signal prior to modulation of the video signal by an  
10 RF carrier.

Moreover, while the comparison portion may be compared to a 50% video level, for example, other comparison portions and reference portions of the video signal may be used. For example, it is  
15 possible to compare a blanking level to the 50% video level or to another video level, or to compare the sync tip level to the blanking level.

An RF carrier reference level corresponding to an RF carrier of the video signal may be provided.  
20 This may be a value which is stored in memory and retrieved for later use by the microprocessor. Means are provided for generating a second error signal corresponding to a difference between the sync pulse tip amplitude prior to normalizing and the RF carrier reference level. Means responsive to the second  
25 error signal adjusts an amplitude of the RF carrier. For example, the second error signal may be coupled to a voltage controlled attenuator (VCA) for adjusting the output of an RF carrier generator. The  
30 video signal at baseband is then modulated on to the adjusted RF carrier.





In a second embodiment, an automated modulation circuit for processing a video signal comprises means for detecting a comparison portion with an associated amplitude, means for providing an RF carrier reference level corresponding to an RF carrier of the video signal, means for generating an error signal corresponding to a difference between the comparison portion amplitude and the RF carrier reference level, and means responsive to the error signal for adjusting an amplitude of the RF carrier.

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## DETAILED DESCRIPTION OF THE INVENTION

Methods and apparatus are presented for automatically controlling the amplitude modulation of video signals.

5        FIG. 1 illustrates an amplitude versus time sketch of a conventional television signal. The trace shown is a baseband signal since it has not yet been modulated with an RF carrier. The amplitude of the voltage of the signal is expressed  
10        in IRE units as established by the Institute of Radio Engineers in the example shown. A blanking level (i.e., front porch) 100, corresponding to zero IRE units precedes a sync pulse 110, which is at a synchronization level of -40 IRE. The sync pulse  
15        shown is a horizontal sync pulse, although the invention can be used alternatively, or in addition, with a vertical sync pulse, or other predetermined level. Moreover, the sync level shown denotes an unscrambled signal. With a scrambled signal, the  
20        sync pulse is attenuated from the level shown by -6 dB or -10 dB, for example. The invention may be used with scrambled or unscrambled signals.

Another blanking level signal (i.e., back porch) 115 follows the sync pulse 110. Next, a  
25        color burst 120, which is 8-10 cycles at 3.58 MHz, is provided. Subsequently, an active video region 130 is provided. The active video region is shown having a smooth curved shape for simplicity.

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Another blanking level 140 follows the active video 130.

Suppression of the sync pulse 110 can be achieved by passing the amplitude-modulated television signal through a 6 dB or 10 dB attenuator during a sync suppression time which extends for a period of about 12  $\mu$ sec., namely from 1.8  $\mu$ sec. before the sync pulse 110 to about 5.7  $\mu$ sec. after the sync pulse 110.

The power level of a transmitted scrambled signal can be increased, e.g., by 3 dB when the sync tip is suppressed to improve the overall signal-to-noise ratio.

FIG. 2 illustrates an amplitude versus time sketch of a television signal with an inverted video portion. With this scrambling technique, as disclosed in U.S. Patent 4,598,318 to Robbins, an inversion level pulse 150 is provided in the sync pulse 110 to designate an amplitude level about which the active video is inverted. In the example shown, the inversion level pulse has an amplitude of 50 IRE, so the active video is inverted about an amplitude, shown by a line 170, at 50 IRE. The inverted video 160 is essentially a mirror image of the non-inverted active video 130 of FIG. 1. All or only randomly selected lines of a video field or frame may be inverted. 50 IRE is a convenient level to use since it is half way between the white level at 100 IRE and the blanking level at 0 IRE. 50 IRE may be considered to be a 50% video level since the video extends from 0-100 IRE. This should

not be confused with percent depth of modulation discussed below.

Other inversion levels may be used, such as 30 IRE, which is the midpoint of the range from -40 to 100 IRE. The reference pulse may be provided in addition to the inversion level pulse when the two differ, but it is convenient to use the inversion pulse as a reference pulse if possible. Any signal which has active video below the blanking level is assumed to be inverted, since somewhere in every field there would be some gray (white) video normally.

In accordance with the present invention, the pulse 150 can serve as a reference level for adjusting the modulation of the television signal. Even if the active video is not inverted, and/or the sync pulse is not attenuated, the reference pulse 150 can be inserted into the sync pulse 110 or other predetermined location in the video signal. For example, lines 22 and/or 23 of the vertical blanking interval may be used. Use of these lines makes it difficult to observe when inversion on line 24 takes place. Any modulator can be modified to provide the reference pulse.

FIG. 3 illustrates a modulated carrier in accordance with the present invention. The modulated carrier corresponds to the baseband signal of FIG. 2. The corresponding IRE level of the modulated carrier is shown on the vertical axis. The modulated carrier is obtained by modulating the baseband signal of FIG. 2 with an RF sine wave

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by 2.0 to obtain the corrected value  $A_{sc}$  (since  $-20 \cdot \log_{10}(2.0) = -6$ ). At block 508, if the attenuation is -10 dB,  $A_s$  is multiplied by 3.162 to obtain the corrected value  $A_{sc}$  (since  $-20 \cdot \log_{10}(3.162) = -10$ ). If the television signal is not scrambled, e.g., in the clear, the sync tip will not be suppressed, so processing will continue directly at block 510, thereby bypassing blocks 506 and 508. Regarding blocks 506 and 508, other multipliers should be used if other attenuation levels are used.

At block 510, the corrected sync tip sample,  $A_{sc}$ , is normalized to a reference level. For example, to normalize  $A_{sc}$  to a value of 50 IRE (at baseband), as discussed previously,  $A_{sc}$  is multiplied by 0.4375 at block 512. Sampling may be realized using an eight bit A/D converter which is built into a microprocessor. Multiplication by 0.4375 (7/16) can be achieved using integer arithmetic by performing four right shifts to obtain 1/16 of the original value, right shifting the original value once to obtain 1/2 of the original value, then subtracting the 1/16 value from the 1/2 value to obtain 7/16 of the original value.

For example, assume an arbitrary  $A_{sc}$  of 221 in decimal, denoted  $221_{10}$ , or in binary,  $11011101_2$ . Right shifting once yields  $01101110$  (e.g.,  $110_{10}$  or  $221/2$ ). Right shifting twice yields  $00110111$  (e.g.,  $55_{10}$  or  $221/4$ ). Right shifting three times yields  $00011011$  (e.g.,  $27_{10}$  or  $221/8$ ). Right shifting four times yields  $00001101$  (e.g.,  $13_{10}$  or  $221/16$ ). Subtraction can be performed using 2's complement

Virtually any reference level may be selected. For example, it is possible to compare a blanking level which is normalized using an appropriate multiplier to the 50% video level or to another video level. Specifically, for a 50% video reference level, a multiplier of 0.583 is used as discussed in connection with FIG. 3.

Generally, any predetermined portion of the video signal may be compared to any selected reference level, with appropriate correction and normalization. The portion of the signal which is compared to the reference level may be referred to as a "comparison portion" of the video signal, while the reference level is obtained from a "reference portion" of the video signal. For example, it may be desirable to use a comparison portion other than the sync tip since the use of the sync tip is sometimes a problem when it is compressed by the modulation process.

30           The example of FIG. 5, where the sync tip is  
compared to the 50% video level is convenient since

50 IRE is often taken as an inversion level for television signals which use inversion of the active video to enhance scrambling. Generally, the sync tip sample is normalized according to the level of the reference pulse which will be sampled for comparison with the normalized sync tip sample. At block 514, the normalized and corrected sync tip value  $A_{scn}$  is stored for later use, e.g., at block 524, discussed below, and/or block 612, discussed in connection with FIG. 6.

At block 516, the reference pulse is sampled to obtain a reference value  $A_r$ . As mentioned in regard to FIG. 3, the reference pulse may be an inversion level pulse in a sync pulse which is used for inverting the active video. The reference pulse is inserted in the video signal even if no inversion or other scrambling is performed. For example, the reference pulse may be inserted in line 22 of the vertical blanking interval. At blocks 518, 520 and 522,  $A_r$  is corrected for attenuation, if required, in the same manner as discussed above in connection with blocks 504, 506 and 508, respectively, to obtain the corrected reference value  $A_{rc}$ .

At block 524, a modulation depth delta term  $\Delta_{md}$  is calculated as  $\Delta_{md} = A_{scn} - A_{rc}$ . Essentially,  $A_{scn}$  is what the signal level should be at the reference level of modulation depth, and  $A_{rc}$  is what the signal level is. Thus, at block 526, if  $\Delta_{md}$  is too low, e.g., less than zero, or less than a threshold value below zero, the modulation depth should be

increased. This can be accomplished by increasing a charge pump value as discussed in connection with FIG. 7. At block 528, if  $\Delta_{\text{md}}$  is too high, e.g., greater than zero, or greater than a threshold value above zero, the modulation depth should be decreased. This can be accomplished by decreasing a charge pump value. The threshold value may correspond to a one-bit error when integer arithmetic is used. Generally, the resolution of the error depends on the demodulator linearity and A/D resolution. The adjustment (i.e., correction) resolution is usually set to make each adjustment step smaller than the measured error. Even with that condition, single bit errors can be ignored, and two-bit errors can be treated as if they were one bit errors. Alternatively, a threshold value of zero may be used. The threshold value essentially defines a band or range about zero where no modulation adjustment occurs.

The process ends at block 530, but is periodically repeated for each channel. It may be desirable to process a subsequent sample from the same channel, or to process samples from other channels on a rotating basis. The rate of drift of the modulation circuitry is expected to be relatively small, so the period for repeating the process can be relatively long, e.g., several seconds or minutes or even longer. Since the repetition frequency is small, low speed, inexpensive circuitry can be used. Additionally, a

single microprocessor can be used for the modulation circuitry of several different channels.

FIG. 6 illustrates an automatic RF carrier level control process in accordance with the present invention. The process may be combined with the process of FIG. 5, or used in a separate control loop. The process begins at block 600. At block 602, a comparison portion such as a sync tip sample value  $A_s$  is obtained. This may be the same as block 502 in FIG. 5, in which case the sample may be obtained from memory if stored previously. Blocks 604, 606 and 608 correspond to blocks 504, 506 and 508, respectively, of FIG. 5.

At block 610, an RF amplitude reference value  $A_{RF}$  is retrieved. This reference portion may be the expected value of 100% of the RF sine wave which is combined with the baseband television signal to obtain a modulated television signal. This reference value, which depends on the particular modulation equipment used, can be retrieved from a memory under the control of a microprocessor.

At block 612, an RF amplitude delta term  $\Delta_{RF}$  is calculated as  $\Delta_{RF} = A_{sc} - A_{RF}$ . Essentially,  $A_{RF}$  is what the signal level should be, and  $A_{sc}$  is what the signal level is. Thus, at block 614, if  $\Delta_{RF}$  is too high, e.g., greater than zero, or greater than a threshold value above zero, the RF carrier amplitude should be decreased. This can be accomplished by decreasing a charge pump value as discussed in connection with FIG. 7. At block 616, if  $\Delta_{RF}$  is too

low, e.g., less than zero, or less than a threshold value below zero, the RF carrier amplitude should be increased. This can be accomplished by increasing a charge pump value. The threshold value may correspond to a one bit error when integer arithmetic is used. Alternatively, a threshold value of zero may be used.

The process ends at block 618, but is periodically repeated for each channel (e.g., programming service). It may be desirable to process a subsequent sample from the same channel, or to process samples from other channels on a rotating, e.g., time sharing, basis.

The RF carrier level control process may generally use any comparison portion and any reference portion. For example, the comparison portion may be a sync pulse tip or a blanking level, and the reference portion may be a blanking portion or 50% video level.

FIG. 7 is an illustration of an automatic modulation control circuit in accordance with the present invention. The circuit, shown generally at 700, may be located at the headend of a CATV systems or at a remote location, for example. A scrambled video signal generator 705 receives a clear (i.e., unscrambled) video input signal and optionally scrambles the signal, for example, by suppressing the horizontal and/or vertical sync pulses, and/or by inverting the active video. The scrambled video signal generator 705 sends a control signal via a path 706 to a microprocessor controller 710 which

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The A/D converter 740 and the microprocessor controller 710 perform the various steps indicated in FIGs 5 and 6. For example, regarding the process of FIG. 5, the sync tip value  $A_s$  is corrected for attenuation, if required, normalized to a reference level, and stored, while the sample reference pulse is also corrected for attenuation, if required. The delta modulation depth term  $\Delta_{md}$  is also calculated.

15           The video signal which is output from the  
scrambled video signal generator 705 is coupled to a  
modulator 760 via a capacitor  $C_1$ , and biased by a  
resistor  $R_1$  which prevents shorting out of the video  
signal. A capacitor  $C_2$  is optionally used to stop  
20 hum and noise from getting into the video signal,  
but is not required. The modulator 760 modulates  
the video signal using an RF carrier from an RF  
carrier generator 780 which is processed by a  
voltage controlled attenuator (VCA) 770. The VCA is  
25 responsive to an RF amplitude control signal to  
adjust the absolute level of the RF carrier.

The video signal output from the generator 705 is similarly biased by a modulation depth control signal which is received by the resistor  $R_1$ .



The RF amplitude control signal is provided by a  
 charge pump 750 in response to an adjustment signal  
 from the microprocessor controller 710. The  
 microprocessor controller 710 may communicate with a  
 5 memory (e.g., RAM) 712 which may store a look up  
 table for converting  $\Delta_{MD}$  and  $\Delta_{RF}$  to corresponding  
 adjustment signals for charge pumps 750 and 755.  
 The memory 712 may also store values such as  $A_{SC}$  for  
 use in both the processes of FIGs 5 and 6 to avoid  
 10 the need to obtain two samples. The memory 712 may  
 optionally be internal to the microprocessor  
 controller 710.

The charge pumps 750 and 755 each contain a  
 diode pair, the output of which is capacitively  
 15 coupled to ground and provided to an amplifier.  
 Each charge pump communicates with the  
 microprocessor controller 710 via two lines which  
 bias the diode pair. Specifically, the delta in  
 modulation depth  $\Delta_{MD}$  will be translated to an  
 20 adjustment signal for the charge pump 755 to provide  
 an increased charge to increase the depth of  
 modulation when the corrected and normalized sync  
 tip sample level  $A_{SCN}$  is less than the corrected  
 reference level  $A_{RC}$ , or to provide a decreased  
 25 charge to decrease the depth of modulation when  $A_{SCN}$   
 >  $A_{RC}$ .

Additionally, the delta in RF carrier amplitude  
 $\Delta_{RF}$  will be translated to an adjustment signal for  
 the charge pump 750 to provide an increased charge  
 30 to increase the RF carrier amplitude when the

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The capacitor/resistor value are chosen to be able to discharge at a rate to follow the highest modulating frequency while, at the same time, the carrier frequency is high enough to allow the capacitor to follow the carrier waveform envelope. Since the ratio of the carrier to modulation is about ten, there are ten carrier waves for each of the highest modulating frequency, which is 4.2 MHz with the NTSC standard.

The modulation circuit 700 can operate in two control loops, one for the depth of modulation and one for the absolute carrier level. Thus, the update period can be different for each loop. Additionally, the circuit 700 can operate in only one of the modes, if desired. The optimal update rate depends on a variety of factors, including the humidity of the location of the charge pumps and the quality of the capacitors and diodes. Transistor base-collector junctions may be used as the diodes because of their superior low leakage qualities.

FIG. 8 is a block diagram of a scheme for providing automatic amplitude modulation of several channels using a common microprocessor controller. Further efficiencies can be achieved by fabricating several circuits with a common microprocessor controller. Dedicated microprocessor controllers for each channel are not required since the errors are small and slowly changing. Thus, the processing cycle can be very slow, e.g., several seconds or minutes or longer.



5           The use of a sync tip as a comparison portion  
and the 50% reference level as a reference portion  
are only example embodiments, as other combinations  
can be used. For example, the blanking level may be  
compared to the 50% level, or the sync tip level may  
10 be compared to the blanking level.

For adjustment of the absolute RF carrier level, the insertion of a reference pulse is not required. Instead, a reference value is stored in a memory and retrieved for comparison with the corrected sync tip pulse. An error term is computed and converted to an adjustment signal for a charge pump which increases or decreases the absolute carrier level accordingly.

Advantageously, the scheme provides automatic modulation control thereby obviating the need for periodic manual adjustments. The required circuitry can be manufactured at a relatively low cost and is suitable for use in remote locations. The present invention is believed to be particularly suitable for use in developing CATV markets where low-cost, low-maintenance equipment is required.

Further efficiencies can be achieved by fabricating several circuits with a common microprocessor controller and memory which service the individual circuits on a time-sharing basis.

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